numerous and well-executed. The principal meteorological instruments are described, with cuts, and in many cases information is given as to cost.

On page 96 the height of Mount Hamilton is given as 4,400 feet; the LICK Observatory, where meteorological observations are taken, is slightly more than 4,200 feet above sea-level. Other accidental errors have not been noticed; absolute freedom from such is hardly to be expected, especially in a first edition.

It may be mentioned, in conclusion, that the mechanical execution of the book is excellent in every way.

THE CLIMATE OF *MARS.*

BY MARSDEN MANSON.

The fact that *Mars* presents phenomena which indicate milder polar climates than exist upon the Earth seems to puzzle many students of astronomy. Instead of endeavoring to account for these phenomena by logical deductions from admitted facts and known laws, some seem to find pleasure in exercising their ingenuity by ascribing remotely possible conditions, and then in accounting for these conditions by processes of argument which strain the faith of their co-workers beyond its limit of elasticity.

The writer will endeavor to show that the climatic conditions, generally admitted to exist upon *Mars*, can be explained without resorting to suppositions and hypotheses bordering near the limits of common sense. The arguments will be simple and fundamental. Until these simple explanations shall be shown to rest upon incorrect premises, or that wrong conclusions have been drawn, the scientific imagination should be restrained within reasonable bounds.

The mean distance of *Mars* from the Sun is about one and one-half times the mean distance of the Earth; and its volume is about one-seventh that of the Earth. Unlike the rest of the planets, its own and other satellites, *Mars* reflects a rich ruddy light—an important factor in interpreting climatic conditions. Upon equal areas the heat and light received by *Mars* is less than one-half that received by the Earth; it by no means follows that its climates are proportionately colder, for the actual amount of

heat a planet receives is not the only prime factor in its surface temperatures. There are other factors which bear an important part, and arguments omitting these are fallacious. It is the omission of these factors which has rendered the climatic conditions prevalent upon *Mars* difficult of interpretation, and has caused some astronomers to doubt the prevalence of milder climates upon *Mars* than upon the Earth. Others have considered the propriety of substituting some other substance than water to account for the formation and disappearance of the polar snow-caps.*

As either pole of *Mars* emerges from its winter, comparatively white spots are observed to encircle it. These spots generally reach down to Lat. 84° or 82°, or 6° or 8° from the pole, although the snow sometimes extends down to latitude 60° to 55°, or through an arc of from 60° to 70°; they disappear in whole or in part as the pole is towards the Sun in the following summer. The disappearance on the edges is rapid, but the true polar spots are persistent for months. These phenomena admit of the simple explanation usually rendered, namely, that these spots are polar snow-caps which form and melt off with the seasons; but the task of explaining how a planet receiving less than half the heat and light which the Earth receives could enjoy so mild a winter and so warm a summer at polar latitudes has been heretofore considered difficult.

Dr. BATES† argues that these polar spots may be fields of carbon di-oxide (CO_2), and his theory is accredited with having much in its favor by Professor CAMPBELL‡ of the LICK Astronomical Department of the University of California. Neither authority accounts for what would have become of any water which may have existed upon *Mars*, and which would have been condensed before the carbon di-oxide; nor why, upon the evaporation of the carbon di-oxide, we do not see the equally white snow and ice which must have been frozen and precipitated before the planet reached the extremely low temperature at which carbon di-oxide congeals. Before this remarkable interpretation can be discussed, it must be shown that water never did exist upon *Mars*, for it would have been congealed first, and would have shrouded the planet in white, upon which surface the con-

* *Publications* A. S. P., Vol. VI., No. 38, page 300.
† *Publications* A. S. P., Vol. VI., pages 300–302.
‡ *Ib.*, page 280.

densation and evaporation of the equally white carbon di-oxide could not be observed. The same is true for any other substitute having a freezing point between that of water and — 109° Fahr.— the freezing point of carbon di-oxide. Whatever may be the freezing point of the substance causing the polar snow-caps, this substance has the highest, not the lowest freezing point of the congealable constituents of the atmosphere of *Mars*, for upon its evaporation we observe the general surface of the planet.

THE OMITTED FACTORS.

In the life of a planet there is a period between the final exhaustion of its own available heat and the reign of solar heat, during which period glacial conditions are extensive and permanent for a great length of time. This period the Earth has manifestly passed through, as continental glaciers once existing have disappeared, and their feeble remnants are yet retreating upwards and polewards in tropical, temperate, and even polar latitudes. This retreat is very slow, but is distinctly noticeable wherever glaciers yet rest. It therefore follows that since the period when these glaciers were most extensive, there has been a general rise in temperature. As this rise is yet in progress, it must be accounted for by laws now active.

It has been previously stated that the actual amount of heat received by a planet was not the sole factor influencing its surface temperatures; other factors are equally and probably more important. Their existence and influence are made apparent in the general rise in terrestrial temperatures since the culmination of the period of great glacial extension over now temperate and tropical areas. One of these factors or causes is the power of the atmosphere to trap heat. TYNDALL* and BUFF† have shown that by contact with the planetary surface solar light and heat-rays are converted into dark heat-rays, and are trapped; and that this power to trap dark heat-rays is held individually and collectively by the various constituents of the atmosphere. Some gases, and notably the odor of flowers, possess this power to a high degree. Now, when this heat-trapping process is inaugurated upon a planet, it is no longer a heat-losing body, but a heat-

* *Proceedings Royal Society*, Vol. XIII, page 160; *Archives des Sciences*, Berne, Vol. V, page 293.

† *Ib.*, Vol. LVII, page 293.

gathering body in space; for its rate of receipt of heat is greater than its rate of loss. The process has a moderate limit fixed by the evaporation of water, which evaporation, when excessive, shuts out solar energy by extensive cloud formation.* The mean surface temperatures of the Earth have thus gradually risen from the lower temperatures prevailing during past glacial extension. As the progress of this rise is yet being recorded by the retreat of glaciers in both hemispheres and at all latitudes, and as it was inaugurated at a comparatively remote period in the past, the factor time has entered into the result as a third important cause. Thus the solar climates of a planet are determined by three prime causes, or factors: first, the actual amount of heat and light received; second, the heat-trapping power of its atmosphere — determining the difference between its rate of receipt and rate of loss of heat; third, the time these two factors or causes have been operating.

In the application of this reasoning to *Mars* we can fix, in general terms, the comparative value of each cause; the logical result of the combination being that *Mars* must enjoy a milder general climate than the Earth.

As regards the first, the amount of heat and light *Mars* receives is readily calculated to be about 0.43 that received by the Earth.

The existence and operation of the second cause is made manifest by the deficiency of blue rays and the excess of red and orange rays in the solar light *Mars* transmits to us, thus establishing the fact that the Martian atmosphere has the power of abstracting and retaining those rays which are most readily trapped by the atmosphere of the Earth. This deficiency in the rays most readily trapped shows that there is a positive difference between the rates of receipt and loss of solar energy; or in other words that *Mars*, like the Earth, is either a heat-gathering body, and that its surface temperatures are yet gradually rising; or, that its surface temperatures are constant, and the excess of solar energy is used in maintaining these constant conditions, and in work upon the planet's surface.

The third cause—the factor time—is necessarily greater than the corresponding factor in the case of the Earth; for *Mars*, having a mass less than one-ninth that of the Earth, lost his

* The climate of *Venus* seems to be thus modified.

internal heat at an earlier period, and therefore became a heat-gathering body at an earlier period than the Earth.

Thus all three of the prime causes are positive in their effects, irrespective of a constant or slowly decreasing source of heat, and omitting the unknown, but positive and constant factor—stellar heat. It is therefore reasonable to conclude that the phenomena observed are correctly interpreted to mean that *Mars* enjoys a milder general climate than the Earth.*

This reasoning admits of application to any planet of any system, and it is reasonable to infer that similar climatic conditions must in time be established upon any planet having a heat-trapping atmosphere.

SAN FRANCISCO, Cal., January 27, 1895.

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* The supposed Martian Arctic explorer, referred to by Professor CAMPBELL, has a trip corresponding to a summer jaunt through Norway and Sweden. Probably an equally pleasant trip awaits future explorers of our polar regions.